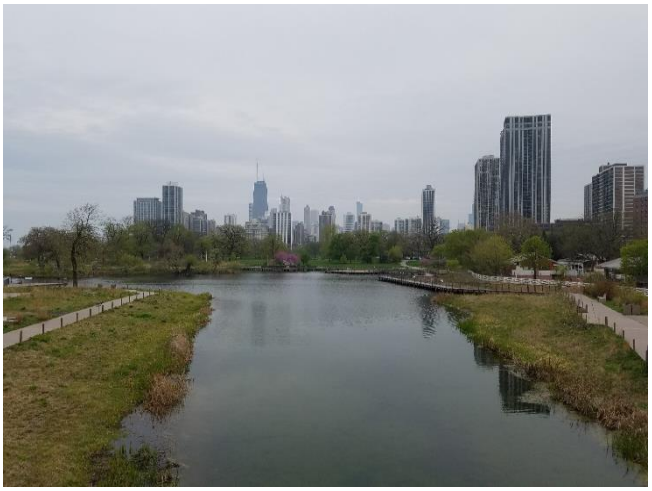

THE URBAN FOREST AND ENVIRONMENTAL JUSTICE

A Review of the Literature

Author: Nicholas P. Boyd

Faculty Adviser: Dr. Nisha Botchwey

Date: April 28, 2017

Table of Contents:

Introduction

Historic Background of Urban Forestry

As the United States becomes increasingly urban, local governments, planners, and nonprofit organizations are alleviating some of the stress on human and environmental health and urban infrastructure systems by turning to natural or 'green infrastructure' (GI), which comprises an "interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife" (Benedict and McMahon 2006). According to Nowak and Walton, urban land area as a percentage of total land area in the U.S. will increase from 3.1% in 2000 to approximately 8.1% by the year 2050, comprising a land area greater than the state of Montana (2005). Urban forests can mitigate the impacts of the urban landscape while providing multiple benefits for environmental quality and community well-being. Urban forest planning and management provides a strategic approach to dealing with the strains on human health and the health of the natural environment caused by increasing urbanization. According to the National Urban and Community Forestry Advisory Council's (NUCFAC's) Ten-Year Urban Forestry Action Plan, "integrating urban and community forestry into all levels of planning will be needed to sustain the ecosystem services and products growing urban populations require, and this translates to a need for added investment" (2015).

Planting trees within urban areas expanded with urban growth that occurred during and after the industrial revolution of the 19th century (Pincetl et al. 2013). Famed landscape architect Frederick Law Olmsted became fascinated by the tree-filled parks he observed in England during this time period and translated that fascination into his designs of numerous American parks, including New York City's Central Park and Boston's Emerald Necklace. However, while industrial-period cities saw the expansion of urban trees to promote utilitarian value, forested areas on the urban fringe were often preserved and maintained for their benefits to urban water quality and quantity. Even at this early point in our nation's urban history, the connection between trees and the health of urban watersheds was understood, although a deeper

understanding of the full range of ecosystem services provided by trees was yet to be attained (Pincetl et al. 2013).

While tree planting in America's residential neighborhoods expanded greatly toward the end of the 19th century, Lawrence suggests that these forestation efforts occurred primarily in affluent communities and overlooked working-class communities, who subsequently came to resent the investment of public funds for tree planting in light of the numerous social causes they felt were more worthy, including affordable housing and public health (2006). However, neighborhood tree planting activities were largely volunteer-based initiatives at this time, with municipal governments directing their tree planting efforts toward heavily trafficked roadways (Lawrence 2006).

The U.S. Forest Service's role in urban forestry took hold in the early 20th century under Gifford Pinchot, the fourth Chief of the U.S. Division of Forestry and the first Chief of the U.S. Forest Service after the institution was renamed in 1905, who "believed that there was a moral obligation to take care of soils and forests" (Pincetl et al. 2013; Forest History Society 2015). Pinchot saw a need to develop a broad constituency in support of the Forest Service's efforts and sought to build strong relationships with diverse regional interests in order to further his forestry goals; this focus on collaboration is still the centerpiece of the Forest Service's approach.

Over the course of the 20th century, federal involvement in urban forestry became increasingly pronounced. In 1964, the Outdoor Recreation Review Commission "called for greater public access to the public lands and for the creation of more public lands in and around major metropolitan areas" (Pincetl et al. 2013). In 1978, Congress passed the Cooperative Forestry Assistance Act which mandated the Forest Service to work in cities, leading to the subsequent establishment of a national Urban and Community Forestry program (Pincetl et al. 2013). Founded in 1976, Tree City USA is a program of the National Arbor Day Foundation that works with the Forest Service and the National Association of State Foresters to "foster tree planting

in urban areas, to develop programs that promote tree planting and to ensure maintenance of trees in perpetuity" (Pincetl et al. 2013; Arbor Day Foundation). More recently, the Forest Service collaborated with Plan NYC in 2011 to establish the national Vibrant Cities taskforce, which lobbied the U.S. Congress on the benefits of urban forestry (Pincetl et al. 2013).

National Decline of the Urban Tree Canopy and Local Efforts to Mitigate That Decline

Due in part to the Forest Service's dissemination of knowledge about the environmental, social, economic, and public health benefits of urban trees, as well as increased strain on traditional grey infrastructure systems for managing stormwater and concern over the growth of urban heat islands, many cities and regions across the country have initiated municipal tree planting and preservation initiatives aimed at preventing urban tree canopy loss and maximizing the benefits that trees can provide in urban areas (Edmondson et al. 2016). However, this renewed enthusiasm for urban tree planting efforts comes after noticeable declines in tree canopy coverage in many urban areas as a direct result of new development and the associated replacement of natural features with impervious surfaces (Randolph 2003). An analysis of tree canopy and impervious coverage change in twenty U.S. cities over an average time period of five years by Nowak and Greenfield (2012) found statistically significant declines in tree canopy coverage in seventeen of those cities[1], while one city, Syracuse, NY, experienced a statistically significant increase in tree canopy coverage of approximately one-percent over five years. The authors attribute this increase to "natural regeneration in concert with limited development or activities that would tend to reduce regeneration," and suggest that the causes of decline are many, including development, disease, and natural hazards (Nowak and Greenfield 2012).

Although efforts to plant and maintain new trees may increase tree canopy coverage in the future, tree cover currently appears to be declining at an "annual net loss of about four million trees per year in urban areas of

1 Cities that experienced a statistically significant decline in tree canopy coverage include: New Orleans, LA; Houston, TX; Albuquerque, NM; Baltimore, MD; Atlanta, GA; Miami, FL; Tacoma, WA; Kansas City, MO; Nashville, TN; New York, NY; Minneapolis, MN; Boston, MA; Los Angeles, CA; Detroit, MI; Chicago, IL; Pittsburgh, PA; and Denver, CO.

the conterminous United States," with implications for the associated ecosystem services provided by trees and their effects on human health and quality of life (Nowak and Greenfield 2012). Increases in impervious surfaces as a result of deforestation have been linked to a number of negative environmental impacts, including decreases in air and water quality and increases in the magnitude of urban heat islands, which have been linked to heat-related mortality and the production of noxious ground-level ozone (Nowak and Greenfield 2012; Akbari, Pomerantz and Taha 2001; Stone and Norman 2006). Benedict and McMahon (2006) support the 40 percent coverage rule for tree canopy proposed by American Forests as a goal for cities east of the Mississippi River "to be environmentally healthy" but they caution that this number may be "out of reach in many urban areas." New Jersey for example, has tree canopy coverage of only 17 percent, which is a fairly typical number for a highly urban eastern city. On the higher side, estimates for Atlanta stand at approximately fifty percent tree canopy coverage (Giarrusso and Smith 2014; Nowak and Greenfield 2012). While the Atlanta metropolitan area currently exceeds the recommended forty percent benchmark, since 1973, the region's tree canopy has declined by 25 percent (Benedict and McMahon 2006). A study by the Georgia Forestry Commission indicates that the Atlanta region lost an average of 50 acres of tree canopy per day from 1991 to 2005 (2005). Thus, even cities with high percentage canopy coverages may be at risk of decline.

In order to prevent further canopy loss in the Atlanta region and elsewhere, tree planting programs must plant trees faster than the rate at which they are lost to development or natural mortality (McDonald 2015). Maintenance of new and existing trees is also important, as the cost of replacing trees is often higher than the cost of preventive maintenance. However, this may not be true in all parts of the country – arid regions may experience higher maintenance costs due to water scarcity and should evaluate the costs and benefits of planting trees carefully to determine the financial viability of investing in urban forestry (Hauer, Vogt, and Fischer 2015). Despite this, the National Urban and Community Forestry Association (NUCFAC) notes that urban forestry needs and services are increasing in most urban areas and municipal programs are transitioning from simply developing urban forestry policies and programs to actively managing the urban

forest as a vital natural resource. According to the Ten-Year Urban Forestry Action Plan, "programs that may have been established as beautification efforts are gradually shifting to programs that focus on providing greater community services and ecosystem benefits (2015)."

Although this shift in perspective has led many urban areas throughout the country to begin valuing and investing in the urban forest as a vital natural asset and as an important component of urban infrastructure, significant gaps exist in the spatial distribution of the urban forest across socioeconomic variables in many cities; these variables are highly context specific and may include income, race and ethnicity, housing tenure (rentership vs. ownership), and/or population density (Schwarz et al. 2015; Heynen, Perkins, and Roy 2006; Danford et al. 2014). There may be similar gaps in the spatial distribution of urban reforestation efforts as well (Heynen, Perkins, and Roy 2006). As cities increase their focus on planting and maintaining trees for the provision of community services and ecosystem benefits, these distributional inequities must be accounted for and planners are accountable to ensure that all residents benefit equally, regardless of their position on the socioeconomic ladder (American Planning Association 2016).

This review of the literature details the current extent of knowledge of the physical, mental, social, and economic benefits of the urban forest, the negative health impacts that can result in areas that are underserved by urban forests, and explores implications for planning, especially with regard to social justice issues that relate to the extent and location of the urban forest in cities across the country. It draws several conclusions for planners to be aware of to inform their work within the urban and community forestry realm.

Methods

This review first identifies peer-reviewed literature, which was mined to establish the current knowledge base about the history of urban forestry; the physical, mental, social and economic benefits of the urban

forest, the negative health impacts that can result in areas that are underserved by urban forests; and the social justice issues that currently arise from unequitable management and coverage of urban forests related to vulnerable populations in cities across the country. Key literature search terms used include: health benefits of urban forestry, social benefits of urban forestry, economic benefits of urban forestry, history of urban forestry, urban forestry for vulnerable populations, environmental justice and urban forestry, and barriers to urban forestry implementation. The bibliographies of these initial articles were also reviewed along with books to identify additional relevant sources.

In addition, grey literature was identified including technical reports and tree plans from various municipalities to supplement information from the peer-reviewed literature concerning the current applied understanding of the benefits of urban trees, urban forestry programs that exist throughout the country, and issues concerning the management, extent and distribution of the urban forest in U.S. Cities. This literature established the current state of the practice of urban forestry and was used to identify pathways towards increasing equity in the distribution of urban forests and urban reforestation programs and policies.

The Benefits of Trees for Physical and Mental Health

Physical Health

Many benefits of trees for human physical health have been cited in the literature, including provision of clean drinking water, fostering increased physical activity, promoting faster healing in hospitals, reduction of heat-related mortality, reduced incidence of cardiovascular-related mortality, improved air quality and related reductions in respiratory-related mortality, reduced incidence of childhood asthma, and improved birth outcomes (Benedict and McMahon 2006; Cotrone 2015; Akbari, Pomerantz, and Taha 2001; Beattie, Kollin, and Moll 2000; Nowak 2002; Lovasi et al. 2008; Wolf 2008; Mitchell and Popham 2008; Donovan et al. 2013; National Urban and Community Forestry Advisory Council 2015; Stone and Norman 2006). However,

one of the most important benefits of trees in urban areas pertains to water quality, which degrades as impervious surface coverages increase. During precipitation events, pollutants are carried by rainwater into surface waters such as streams, rivers and lakes (Schwab 2009). As surface waters provide more than half of the nation's drinking water, there is potential for polluted water to produce negative human health impacts (Centers for Disease Control and Prevention 2009b). Even though municipal wastewater treatment facilities treat surface water before making it available for consumption, pollutants may still enter drinking water from treatment failures or high-level of contamination with chemicals such as lead (Centers for Disease Control and Prevention 2012). Trees, due to their ability to filter pollution and to absorb or slow the movement of water, can be very effective in improving water quality and reducing the incidence of hazardous flooding events (Cotrone 2015, Beattie, Kollin, and Moll 2000; Schwab 2009). As noted by Beattie, Kollin, and Moll (2000), "it is apparent that urban forests are indicators of the environmental quality of a community and that they provide measurable benefits, in particular: reducing stormwater flow and improving water quality."

According to Benedict and McMahon (2006), "each year in Chicago, the urban tree canopy removes 15 metric tons of carbon monoxide, 84 metric tons of sulfur dioxide, 89 metric tons of nitrogen dioxide, 191 metric tons of ozone, and 212 metric tons of particulates." Each of the aforementioned pollutants is a criteria pollutant for which air quality standards have been set under Title I of the 1990 amendments to the United States Environmental Protection Agency's (USEPA's) Clean Air Act and all have been linked to negative human health outcomes (US Environmental Protection Agency 2016). A study by Lovasi et al. (2008) used data on childhood asthma prevalence for children aged 4-5 and asthma-related hospitalization for children under the age of 15 for 42 health service catchment areas in New York City and found that street trees were associated with a lower prevalence of childhood asthma. Noting significant disparities in childhood asthma prevalence along racial, ethnic and socioeconomic lines, the authors concluded that "street trees may explain geographic variation in the prevalence of asthma within urban environments. Trees may help prevent asthma, either by encouraging outdoor play or through an effect on local air quality" (Lovasi et al. 2008).

Nowak (2002) details four mechanisms by which trees impact air quality, including temperature reduction, removal of air pollutants, emission of volatile organic compounds (VOCs) and tree maintenance emissions, and energy effects on buildings. While temperature reduction, removal of air pollutants and reductions in cooling-energy use in buildings have all been linked to positive physical health outcomes, it is important to highlight that the emission of high quantities of VOCs by some tree species, including poplars and willows, is associated with negative health outcomes, as VOCs are a precursor to the formation of ozone and nitrous oxide, which are hazardous to human health (Nowak 2002; Benedict and McMahon 2006; Karlik and Pittenger 2012). However, Nowak notes that "because VOC emissions are temperature dependent and trees generally lower air temperatures, increased tree cover can lower overall VOC emissions and, consequently, ozone levels in urban areas" (Nowak 2002).

A study by Donovan et al. (2013) examined the relationship between trees and human health using evidence from the spread of the emerald ash borer, an invasive pest that is responsible for the rapid and widespread death of ash trees throughout the country. Specifically, the study analyzed the association between the spread of the emerald ash borer and increased cardiovascular- and respiratory-related mortality across 15 states, finding that loss of trees to the emerald ash borer was associated with increased mortality from those causes (Donovan et al. 2013).

In a study by Ulrich (1984), the rate of recovery for hospital patients recovering from gall bladder removal surgery was compared for patients in rooms with views of natural vegetation and patients in rooms with a view of a brick wall. Patients with a view of natural scenery were found to recover faster than their counterparts and also required less pain medication (Ulrich 1984). Additionally, a 2011 study by Donovan et al. examined the relationship between access to nature and birth outcomes, finding that "mothers living

in Portland, OR with more tree canopy within 50 meters of their homes, or who lived closer to open space, were less likely to have a baby that was small for gestational age" (Donovan et al. 2013).

In light of the obesity and chronic disease epidemics in the U.S., recent research has explored the relationship between trees and physical activity. Annually, approximately 300,000 premature deaths result from chronic diseases, which are non-communicable diseases of long duration and typically slow development, including cardiovascular diseases, chronic respiratory diseases, diabetes, and cancer (World Health Organization 2016). Although a moderate amount of regular physical activity has been established as an effective strategy for reducing and managing the incidence of many chronic diseases (Office of Disease Prevention and Health Promotion 2008; Centers for Disease Control and Prevention 2009a; Durstine et al. 2013), Wolf notes that "more than 50 percent of U.S. adults do not get enough physical activity to provide health benefits; 24 percent are not active at all in their leisure time. Activity decreases with age and sufficient activity is less common among women than men, and among those with lower incomes and less education" (2008). Research on this trend has revealed that the design of the built environment influences a range of behaviors, including those related to physical activity. The presence of trees and other vegetation in outdoor environments have been shown to be positively associated with physical activity (Pretty et al 2005); one finding suggests that after sidewalks and trails have been constructed, the introduction of natural elements impacts motivation to engage in physical activity (Suminski et al. 2005). Additional evidence indicates that commonly vegetated areas, such as parks and open space, support outdoor physical activity (Giles-Corti et al. 2005; Wells et al. 2007). Perhaps most telling is the finding that "people in large cities perceive themselves to be generally more healthy if a greater percentage of the living environment is greenspace, are inclined to be more active, and claim the ability to relax faster" (Wolf 2008).

Mental Health

Trees have also been linked to mental health benefits, including reduced stress and mental fatigue, reduced aggression, and enhanced emotional and cognitive development and improved behavioral outcomes in youth

(Benedict and McMahon 2006; Wolch, Byrne, and Newell 2014; Kuo and Sullivan 2001a; NUFAC 2015; Ernston 2013; Ulrich 1981; Ulrich et al. 1991; Lee and Maheswaran 2010). According to Kaplan and Kaplan (2003), "people are attracted to environments that permit exploration and understanding and that offer nature with its restorative properties." Restorative properties provide broad psychological benefits to people that can be realized even in dense urban environments where the availability of greenspace is limited. Importantly, there is evidence to suggest that species diversity within urban greenspaces increases psychological benefits to people. Fuller explored this connection in 15 urban greenspaces in the UK by assessing habitat and species diversity and conducting semi-structured interviews with 312 visitors to these spaces; interviews were designed to assess measures of well-being with a focus on "greenspace as a source of cognitive restoration, positive emotional bonds, and sense of identity (Fuller et al. 2007)." The authors found positive correlations between species diversity and human well-being, noting that "the degree of psychological benefit was positively related to species richness of plants" (Fuller et al. 2007).

Two important studies by Ulrich shed light on the stress reducing effects of exposure to vegetation, even when the exposure is merely to images and not actual vegetation. In the first, participants were presented with a series of color slides in order to compare the stress reducing effects of visual exposure to natural scenes containing vegetation and water to those of urban scenes lacking these features (Ulrich 1981). The study found that "people benefit most from visual contact with nature, as opposed to urban environments lacking nature, when they are in states of high arousal and anxiety. For individuals experiencing stress or excessive arousal, nature views appear to reduce arousal more effectively than urban scenes, and hence are more beneficial in a psychological sense" (Ulrich 1981). In the second study (Ulrich et al. 1991), 120 participants watched a stressful movie and immediately afterward were shown one of six different videos depicting either natural or urban environments. After analyzing stress recovery data gathered from participant self-reports and physiological tests, the study concluded that "recovery was faster and more complete when subjects were exposed to natural rather than urban environments" (Ulrich et al. 1991).

Similarly, a study by Jiang et al. (2016) found that participants who viewed a 6-minute video depicting tree canopy density of approximately 60 percent experienced a 60 percent reduction in stress levels compared to participants who watched an equal length video depicting approximately 2 percent tree canopy density (National Urban and Community Forestry Advisory Council 2015).

A study by van den Berg et al. assessed the effects of exposure to actual vegetation and greenspace on stress in a sample of 4,529 residents of the Netherlands (2010). Controlling for age, income, education level, gender, and level of urbanity, individual health data were analyzed, including the number of health complaints within the past 14 days, along with perceived psychological health and perceived general health. Greenspace was defined to include forests, nature conservation areas and vegetated urban and agricultural areas, but did not include vegetation immediately proximate to houses. The results indicated that "the relationships of stressful life events with number of health complaints and perceived general health were significantly moderated by the amount of green space in a 3-km radius. Respondents with a high amount of green space in a 3-km radius were less affected by experiencing a stressful life event than respondents with a low amount of green space in this radius" (van den Berg et al. 2010). This highlights an important role for trees and other natural features as stress buffers.

In support of Benedict and McMahon's (2006) notion that urban forests provide "restorative experiences that reduce mental fatigue and stress," a study by Kuo and Sullivan (2001a) randomly assigned 145 women to a number of architecturally identical apartment buildings within a public housing development in Chicago, IL, and examined the potential for trees and other vegetation to reduce aggression. The authors found that "levels of aggression and violence were significantly lower among individuals who had some nearby nature outside their apartments than among their counterparts who lived in barren conditions" (Kuo and Sullivan 2001a). Additionally, the findings supported the hypothesis that the reductions in aggression resulted from

reductions in mental or directed-attention fatigue, which is characterized by attention deficits, diminished cognitive functioning, diminished impulse control and heightened irritability.

In summarizing the work of William James on mechanisms of human attention, Kaplan describes directed attention as a form of voluntary attention "to be employed when something [does] not itself attract attention, but when it [is] important to attend nonetheless;" of particular importance to this definition is the "centrality of effort in the employment of this kind of attention" (Kaplan 1995). Because directed attention requires effort, it is susceptible to fatigue and requires replenishment when the capacity to voluntarily attend to a stimulus becomes depleted. Research on Attention Restoration Theory has focused on mechanisms for counteracting this fatigue and thus restoring the capacity for directed attention (Kaplan 1995). Kaplan first put forth the concept of directed-attention fatigue and its connection to natural environments in 1995, suggesting that "many of the most effective settings for recovering from directed-attention fatigue involve the natural environment" (Kaplan and Kaplan 2003). Noting that the symptoms of mental fatigue are "well-established psychological precursors to violence," Kuo and Sullivan (2001a) point to a substantial and growing body of literature that supports this relationship. Children have been shown to derive unique mental health benefits from exposure to natural settings. A study by Faber-Taylor et al. (2001a) explored the relationship between exposure to nature and attention functioning in children with Attention Deficit Disorder and found that "children function better than usual after activities in green settings and that the "greener" a child's play area, the less severe his or her attention deficit symptoms."

Exposure to nature also has profound impacts for low-income urban children. A study by Wells examined the relationship between the amount of vegetation near the home and the cognitive functioning of low-income urban children who had recently moved; assessments of vegetation and cognitive functioning were conducted both before and after moving (2000). The results suggested that children who moved to a home

with more nearby vegetation than the home they came from were likely to have higher levels of cognitive functioning after the move (Wells 2000).

Another study by Faber-Taylor et al. (2001b) measured the amount of natural vegetation near the home in relation to measures of self-discipline in urban children. With regard to concentration, impulse control, and delay of gratification, the authors found that "for girls, green space immediately outside the home can help them lead more effective, self-disciplined lives" (Faber-Taylor et al. 2001b). The study did not find a relationship between near-home nature and self-discipline in boys, which the authors suggest may be due to the fact that boys tend to play further away from home than girls (Faber-Taylor et al. 2001b). They recommend that future studies examine the relationship "between levels of nature in boys' most typical play spaces and their self-discipline" (Faber-Taylor et al. 2001b). In a review of findings on the relationship between childhood development and exposure to nature, Strife and Downey found that "the positive effects of nature exposure include improved cognitive functioning (including increased concentration, greater attention capacities, and higher academic performance), better motor coordination, reduced stress levels, increased social interaction with adults and other children, and improved social skills" (2009).

The Benefits of Trees for Social and Economic Health

Social Health

The most widely cited social benefits of trees pertain to enhanced community aesthetics, crime reduction, and increased social interaction, which has been linked to a number of positive outcomes (Benedict and McMahon 2007; Kuo and Sullivan 2001b; Kuo 2003; Wolfe and Mennis 2012; Sullivan, Kuo, and DePooter 2004). In a review of findings related to the contributions of trees to the health of social ecosystems, Kuo (2003) evaluated a series of studies conducted in Chicago which involved extensive data collection including person-space observations, interviews, and police crime reports and housing authority records. The results of these studies indicated that "tree and grass cover were systematically linked to a wide range of social

ecosystem indicators. These indicators included stronger ties among neighbors, greater sense of safety and adjustment, more supervision of children in outdoor spaces, healthier patterns of children's play, more use of neighborhood common spaces, fewer incivilities, fewer property crimes, and fewer violent crimes" (Kuo 2003). Of central importance to the benefits observed is the theory of defensible space, which holds that crime rates and relationships between neighbors are significantly impacted by the physical characteristics of a neighborhood. Spatial arrangements that encourage the use of common space are believed to promote informal contact among residents and surveillance of the shared space, while arrangements that discourage use of common space may isolate residents and promote crime (Newman 1996). Kuo's findings suggest that the presence of trees and grass in common spaces encourages their use, leading to many beneficial social outcomes (Kuo 2003).

There are two different accounts of the relationship between vegetation and crime. The first holds that vegetation facilitates crime by providing a space for criminals to hide from victims and potential witnesses. This is a longstanding view and has been used as justification for removing vegetation in the hope of deterring criminal activity (Wolfe and Mennis 2012). The second account is more recent and claims that vegetation may deter crime by increasing surveillance and alleviating important psychological precursors to violence, including irritability, decreased attentiveness and decreased impulse control (Wolfe and Mennis 2012; Kuo and Sullivan 2001b). In support of the first view, Shaffer and Anderson (1985) examined undergraduate students' perceptions of the attractiveness and security of 180 photo views of parking lots. Although the students generally ranked parking lots with more vegetation as being more attractive, their perceptions of security were only higher when vegetation appeared to be intentional and well maintained (Shaffer and Anderson 1985). Extrapolating this finding to the neighborhood scale, Wolfe and Mennis (2012) suggest that "vegetation that is overgrown and unkempt in a neighborhood indicates a lack of care for the physical environment that reflects social disorder. This disorder, perceived by the community, inhibits mechanisms of community control, thereby fostering an environment of crime opportunity." Wolfe and

Mennis' suggestion is in line with the view espoused by 'broken windows theory,' first articulated by James Q. Wilson and George Kelling in a 1982 article in *Atlantic Monthly*. They postulated that "broken windows and other unchecked social and physical disorder are direct antecedents to criminal behavior" (Maskaly and Boggess 2014). In another study of the relationship between crime and vegetation, Nasar and Fisher (1993) interviewed 166 college students to assess cues to the fear of crime on a college campus and found that low-canopy trees and dense shrubs were perceived to potentially facilitate crime, suggesting that visibility plays a role in how trees and vegetation might impact perceptions of criminal activity.

In spite of the entrenched view that vegetation facilitates crime, a growing body of research now shows that vegetation can actually inhibit crime. A key mechanism by which vegetation may achieve this effect is through surveillance, which was famously discussed by urbanist Jane Jacobs in *The Death and Life of Great American Cities* (Jacobs 1961). Jacobs theorized that increased use of public space provided for a greater number of potential observers of criminal activity within the space, effectively deterring crime. This idea was subsequently incorporated into Oscar Newman's formulation of defensible space theory (1972) and Paul Stanley's (1976) landmark work, *Crime Prevention Through Environmental Design* (Kuo and Sullivan 2001b). By making public spaces appear more attractive, purposeful and defensible, research suggests that vegetation incorporated into those spaces as an environmental design element can increase their use and thus indirectly increases surveillance (Stanley 1976; Kuo and Sullivan 2001b). Additionally, Newman (1972) suggests that the implication of surveillance may be enough to deter crime, even if a space is not actually being actively observed.

In a study of the relationship between vegetation and the use of outdoor public spaces, Coley et al. (1997) observed one high-rise and one low-rise housing complex in a public housing development in Chicago. The results indicated that presence of vegetation was associated with increased use of public spaces; in addition, vegetated spaces attracted larger groups of people than did barren spaces and also encouraged a mix of adults

and children, with dense clusters of trees located close to buildings attracting larger groups as well (Coley et al. 1997). In reviewing this finding, Wolfe and Mennis (2012) note that "vegetated public environments that encourage greater numbers, and age diversity, of users can create social contexts that suppress crime." This conclusion was supported by a study (Kuo and Sullivan 2001b) that evaluated vegetation and crime rates for 98 apartment complexes in a public housing development in Chicago. The findings indicated that "although residents were randomly assigned to different levels of nearby vegetation, the greener a building's surroundings were, the fewer crimes reported. Furthermore, this pattern held for both property crimes and violent crimes" (Kuo and Sullivan 2001b).

Kaplan and Kaplan proposed that a second mechanism by which vegetation may inhibit crime is by mitigating the symptoms of mental fatigue, which have been noted as psychological precursors to violence (1989). They posited a mechanism called Attention Restoration Theory to explain the effect of nature on mental fatigue. They suggest that the many demands contemporary life places on directed or voluntary attention lead to fatigue over time, diminishing ones' capacity to sustain attention, control impulses, and maintain positive mood. Because natural settings require less directed and more involuntary attention than typical urban environments, they provide opportunities for restoration and reduction of mental fatigue, thus mitigating inclinations toward violence or other criminal behaviors (McDonald 2015). Similarly, in a case study of Philadelphia, Wolfe and Mennis examined crime rates at the census tract level and found that "vegetation abundance is significantly associated with lower rates of assault, robbery, and burglary, but not theft" (2012). The authors attributed this relationship to the dual mechanism of increased surveillance and mental restoration caused by increased vegetation, but they noted an important limitation that crime may merely be displaced from vegetated neighborhoods to less vegetated neighborhoods. If the primary mechanism by which vegetation suppresses crime is mitigating the symptoms of mental fatigue, no displacement should be expected. However, if increased surveillance as a result of nearby vegetation is the

primary mechanism for crime suppression, displacement of crime to less vegetated neighborhoods could be expected (Wolfe and Mennis 2012).

Economic Health

Commonly cited benefits of trees for economic health include the provision of ecosystem services, increased residential property values and municipal property tax revenues, and attraction of more shoppers and increased economic activity to commercial districts (American Forests 1997; Benedict and McMahon 2006; Coder 1996; McDonald 2015; Lerner and Poole 1999; Anderson and Cordell 1988; Seila and Anderson 1982, 1984; Donovan and Butry 2010; Schwab 2009; Wolf 1999). An ecosystem service occurs when the natural environment supplies something that people demand, improving quality of life and well-being. These services can include the provisioning of goods such as fresh water and agricultural products; regulatory functions including protection of drinking water quality, heat mitigation, air purification, and stormwater management, and; cultural functions, such as improving aesthetics, providing opportunities for recreation, tourism, and physical and mental health, and promoting biodiversity (McDonald 2015).

The American Planning Association notes that the ecosystem services provided by trees serve an important economic function that is "often discounted or ignored in development decisions. These "ecosystem services" are extremely valuable and need to be considered in any evaluation of benefits" (Schwab 2009). For example, many of the previously mentioned physical benefits of trees, including air and water purification and reductions in urban heat, have traditionally been thought of as free social goods that are not typically incorporated in economic decision making. However, "undervaluing these services in economic decisions makes the forests supporting them more vulnerable to development and conversion to other uses, often significantly increasing real economic costs for environmental protection after the damage has been done. Valuing the benefits of the urban forest thus contributes to an understanding of ecosystem services" (Schwab 2009).

An important feature of ecosystem services is that they often provide cost savings over the construction and use of traditional grey infrastructure. According to the nonprofit organization American Forests, trees in metropolitan areas across the country provide a stormwater retention value of $400 billion by removing the need to construct and maintain traditional retention facilities (American Forests 1997).

National studies indicate that lands conserved for stormwater retention and flood prevention "show an eight-to-one dollar savings ratio versus man-made flood-control structures" (McDonald 2015). In a 1999 report, the Trust for Public Land estimated that 27 percent of the total land area of Atlanta was covered by trees, providing $15 million in annual air quality benefits and $883 million in savings by removing the need for traditional stormwater retention infrastructure (Lerner and Poole 1999). By increasing tree cover to 40 percent of total land area, the report anticipated an additional $7 million in economic benefits to air quality and $358 million in stormwater retention savings (Lerner and Poole 1999).

In a 2014 assessment of Atlanta's urban tree canopy, the Georgia Tech Center for Geographic Information Systems and the Center for Quality Growth and Regional Development estimated that in October 2008, tree canopy coverage represented nearly 50 percent of the City's total land area (Giarrusso and Smith 2014). While this suggests that the economic benefits of Atlanta's urban trees may have already exceeded the Trust for Public Land's estimations, considerable new development has occurred since 2008.

Much work has been done over the past three decades to determine the relationship between trees and real estate values, especially with regard to residential properties. One of the first studies to explore this relationship (Anderson and Cordell 1988) involved a survey of actual sales prices of 844 single family residential properties in Athens, Georgia over a two-year period. Findings indicated that "landscaping with trees was associated with a 3.5 - 4.5 percent increase in sales prices", with an "estimated increase of $100,000 (1978 dollars) in the city's property tax revenues." (Anderson and Cordell 1988). Seila and Anderson (1982;

1984) conducted two surveys of Georgia homebuilders to assess the costs of preserving trees when building homes on wooded lots. Reports from homebuilders consistently estimated an average seven percent increase in sales price for homes on wooded lots compared to otherwise identical homes on unwooded lots (Seila and Anderson 1982, 1984; Anderson and Cordell 1988). According to an ARBOR National Mortgage survey administered to real estate agents throughout the country, 85 percent of the 1,350 respondents believed that homes with trees could be sold more easily than homes without trees (Schwab 2009). A more recent study (Donovan and Butry 2010) involved visual observation of over 3,000 single-family homes in Portland, Oregon, to assess the number, location, condition, type, and size of street trees fronting property. Findings revealed that street trees were associated with a three percent increase in median sale price, amounting to nearly $9,000 in Portland; additionally, benefits spilled over to adjacent property owners as well. Street trees were also associated with a reduction in the amount of time a home was on the market, with attractive tree-lined homes selling approximately two days sooner than less attractive homes with few or no trees. In total, the study concluded that trees in Portland add an estimated $54 million in value to residential properties annually, with $15.3 million in associated increases to city tax revenues (Donovan and Butry 2010; McDonald 2015).

Research shows that the effect of trees on commercial activity is palpable. In a study of several cities from across the country (Wolf 1999; Schwab 2009), qualitative interviews and quantitative surveys were used to examine the potential impacts of trees on the revitalization of business districts, with results indicating broad benefits provided by trees. Shoppers reported improved perceptions of product pricing and quality, business quality, interaction with business employees, facilities maintenance, and visual attractiveness of business districts when trees were present. Shoppers were also willing to travel greater distances to shopping districts, spend more time there, and pay more for parking when a shopping district had trees, especially large and well-maintained trees. Interestingly, business people ranked business districts with trees lower than visitors

and ranked treeless districts higher than visitors, suggesting a lack of awareness of the positive economic implications of providing well-maintained vegetation for shopping behavior (Wolf 1999).

Urban Trees and Vulnerable Populations

Perceptions of the Urban Forest

In recent years, a considerable body of research has examined the relationship between trees and vulnerable or disadvantaged populations, linking this nexus to the larger issue of environmental justice (Danford et al. 2014; Pincetl 2010; Wolch, Byrne, and Newell 2014; Heynen, Perkins, and Roy 2006; Schwarz et al 2015; Jennings, Gaither, and Gragg 2012; Schwab 2009; Landry and Chakraborty 2009). According to the U.S. Environmental Protection Agency (EPA), environmental justice is "the *fair treatment and meaningful involvement* of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. It will be achieved when everyone enjoys: 1) the same degree of protection from environmental and health hazards, and 2) equal access to the decision-making process to have a healthy environment in which to live, learn, and work" (US Environmental Protection Agency 2016). In seeking to provide a more nuanced conception of environmental justice, Groth, Miranda and Sandberg (2013) define it as "ensuring equal human health and environmental protection for all, with special consideration for communities who are disproportionately burdened by environmental pollution and are more likely to be economically and socially disadvantaged."

Historically, the environmental justice movement has focused primarily on ending or preventing exposure to harmful pollutants and industrial activities in socially and economically disadvantaged communities. However, in recent years, this focus has been broadened to include the improvement of access to environmental amenities, including trees, thus encouraging equity in the distribution of ecosystem services and providing enhancements to human health and quality of life (Schwarz et al. 2015; Danford et al. 2014; Jennings, Gaither, and Gragg 2012). A number of studies have now shown that tree canopy coverage in

urban settings is often inequitably distributed across socioeconomic lines, although "researchers have found that cities differ in which socioeconomic factors are associated with canopy cover" (Danford et al. 2014). The distribution of trees often results from a combination of current and historic drivers that are unique to location, but low-income is typically associated with disproportionally low tree canopy coverage, regardless of location, while race and ethnicity may actually be correlated with increased tree canopy coverage in some places (Danford et al. 2014). In addition to income and race and ethnicity, other socioeconomic factors that have shown an association with tree canopy coverage include housing tenure (rentership vs. ownership) and population density (Schwarz et al. 2015; Heynen, Perkins, and Roy 2006; Danford et al. 2014).

Since socioeconomic inequities in tree canopy coverage constitute an environmental injustice, attempts are being made to better understand precisely which factors drive tree canopy cover, which may help inform efforts by planners to engage with the appropriate communities and correct injustices. However, as the American Planning Association notes, "even though urban forest activists have attempted to engage these communities in greening their neighborhoods, Madeline Williams, Executive Director of the National Association of Black Environmentalists, believes that residents have been apathetic about such efforts. She attributes this attitude to their struggle with day-to-day economic and social problems, which then contribute to social and psychological barriers, which then preclude interest in improving their environment" (Schwab 2009). Urban forestry initiatives that aim to address the needs of environmental justice populations must take these factors into account in order to develop effective strategies.

In a study of Milwaukee, Heynen, Perkins, and Roy explored the distribution of urban tree canopy across socioeconomic dimensions and found that "residential canopy cover is distributed unevenly based on household income, housing-market characteristics, and racial and ethnic factors" (2006). Additionally, the results indicated that "the Hispanic population suffers from an inequitable distribution of canopy cover in conjunction with a lack of the fence-line trees that are found in other disinvested communities" (Heynen,

Perkins, and Roy 2006; Jennings, Gaither, and Gragg 2012). This finding was particularly interesting in light of the authors' hypothesis that African-American communities would also suffer an inequitable distribution of tree canopy coverage. In addressing this counterintuitive finding, the authors noted that fence-line trees, which are trees that grow along fences and building foundations as a result of unintentional germination, were preemptively removed in many Hispanic communities before they could cause damage, whereas in African American communities, these trees were often removed only after they had caused property damage. Noting this apparent difference in the "degree and timing of property maintenance" in different disinvested communities, the authors concluded that "removal of the fence-line forest in African-American communities is likely to create substantial spatial unevenness in the future as a significant component of these communities' forest is lost" (Heynen, Perkins, and Roy 2006).

Similarly, Danford et al. (2014) studied the distribution of urban tree canopy in Boston and found that while low-income neighborhoods were associated with disproportionately low tree canopy coverage, some minority neighborhoods were weakly correlated with increased coverage. Accounting for the fact that the socioeconomic factors affecting tree canopy distribution differ by location, the authors suggest that "in Boston some of the higher percentage minority neighborhoods are more distant from the high-density downtown which has fewer trees; and/or the resultant tree canopy could be the result of abandonment of property, which results in urban forests "regenerating" on vacant lots. As a result, low income seems to be a more significant environmental justice indicator than minority status in the city of Boston" (Danford et al. 2014).

While some of the findings reported by Heynen, Perkins, and Roy (2006) and Danford et al. (2014) were counterintuitive, a study by Landry and Chakraborty (2009) produced results that fully supported the hypothesis that low tree canopy is directly correlated with factors such as low income, high rentership and high concentration of minority populations. In their study of Tampa, Florida, Landry and Chakraborty

(2009) showed that public right-of-way trees were inequitably distributed with respect to race and ethnicity, income and housing tenure, finding a "significantly lower proportion of tree cover on public right-of-way in neighborhoods containing higher proportion of African-Americans, low-income residents, and renters."

Urban Forestry Programs and Tools for Vulnerable Populations

As tree planting programs have become increasingly common in cities across the country, it deserves mention that "the magnitude and even the direction of the impacts of trees on specific urban environments have seldom been measured directly. In addition, there has been little research on the historical, cultural, political or institutional origins of such programs, or on their implementation process" (Pincetl et al. 2013). The benefits of active living, physical healing, and mental restoration provided by urban green spaces are some of the many positive externalities that are largely underreported (Wolf and Robbins 2015). Also, it has been noted that while many urban forestry plans include goals pertaining to environmental justice, data on progress towards achieving those goals is typically scarce or nonexistent (Schwarz et al. 2015). Since little is known about the ways in which vulnerable populations have been impacted by tree planting efforts, it is thus difficult to determine which existing programs have been most successful in creating a more equitable distribution of urban tree canopy cover. Additionally, as previously mentioned, Lawrence has pointed to the fact that, historically, working class residents resented the urban tree planting initiatives they observed in wealthier communities, feeling that the money invested in greening neighborhoods could be used for more worthy causes, such as affordable housing or education (2006). Research on present-day resistance to tree planting and other green infrastructure initiatives suggests that low-income residents often fear that investment in green spaces is a precursor to gentrification of their neighborhood, providing another reason to reject these initiatives (Wolch, Byrne, and Newell 2014, Curran and Hamilton 2012).

Conclusions and Future Research

Increased urbanization beginning with the industrial revolution and national declines in urban tree canopy coverage in recent decades have resulted in strains on human and environmental health, with increased

burden placed on urban infrastructure systems throughout the country. Efforts to restore and manage our green infrastructure, including urban forests, have shown diverse physical, mental, social and economic benefits that are reducing many of the negative impacts urbanization produces. However, several studies have now shown that existing socioeconomic inequities in the distribution of urban forests throughout the country result in high-income residents typically receiving the majority of the benefits of urban trees. While the precise socioeconomic factors that drive the distribution of tree canopy are dependent on the unique local context, this broader finding has implications for planners as they work to develop tree planting and maintenance strategies.

A starting point for planners in ensuring future equity in the distribution of urban forests is the development of robust regulations and policy tools that support human and environmental health. One such tool is the municipal tree ordinance, which can enhance tree planting efforts by ensuring that residents and businesses are accountable for trees that are damaged or removed, thus helping to prevent net tree canopy loss. Regulations should be reviewed across the locality to ensure tree protection and management goals are working in concert. The American Planning Association recommends that tree ordinances be incorporated into the local development code to ensure that developers are aware of their existence (Schwab 2009). If they are instead adopted in isolation, developers are less likely to adhere to the regulations. Participants at an American Planning Association symposium on tree ordinances reported that "too many tree ordinances are stand-alone laws that are not incorporated into zoning, subdivision, or other development codes, and, consequently, go unnoticed by the development community" (Schwab 2009). By ensuring high visibility of local tree ordinances, tree canopy loss can be avoided as efforts to equitably expand tree canopy move forward.

In addition to advocating for and developing robust regulatory tools, planners can support the development of collaborative governance structures to facilitate the management and implementation of urban forestry programs. By advocating for careful planning, transparency among partners, and sustainable funding

sources, planners can ensure that diverse stakeholders are engaged in the production and management of the urban forest, thus increasing the likelihood of an equitable distribution of tree canopy cover. Planners can also facilitate broad community involvement to help ensure that urban forestry programs meet diverse community needs and desires while promoting education on the benefits of trees and the importance of short- and long-term maintenance and stewardship. To address residents' gentrification concerns, planners can align tree planting and urban reforestation with affordable housing efforts. This helps to ensure affordable housing's long-term availability and thus more low-income residents benefiting from the greening of their communities.

Increasing and maintaining urban forests while advancing goals related to equity is not limited to creating the proper regulatory frameworks or facilitating community engagement and collaborative governance. Planners can also spearhead efforts to analyze patterns of existing tree canopy distribution at the municipal level in order to determine which socioeconomic factors, if any, are associated with the distribution of trees. By mapping patterns of inequity, planners can develop data-driven approaches to help inform subsequent community engagement efforts and funding decisions. Local governments should undertake a tree canopy assessment to obtain spatial data about tree canopy coverage and distribution. Comparing this with census and other data, such as locations of parks and other open spaces will help them ensure that social equity disparities are identified and resolved through efforts such as community tree planting projects or establishment of community parks, trails and gardens.

Additionally, planners can lead efforts to conduct program evaluation of tree planting and maintenance initiatives in order to determine their impacts on the distribution of trees and the anticipated benefits of increased tree canopy to vulnerable populations. By gathering data and measuring quantifiable program impacts, planners can determine the appropriate benchmarks by which program success or weakness can be determined; this can help inform evidence-based approaches to planting and maintaining trees and engaging with historically underserved communities in the future. Based on the findings of this review, future research

should seek to explore gaps in program evaluation, as data on the impacts of urban tree planting and maintenance programs on vulnerable populations is often scarce or nonexistent.

Works Cited

Akbari, H., M. Pomerantz, and H. Taha. 2001. "Cool Surfaces and Shade Trees to Reduce Energy Use and Improve Air Quality in Urban Areas." *Solar Energy* 70 (3): 295–310.

American Forests. 1997. "The State of the Urban Forest Report: Assessing Tree Cover and Developing Goals." Washington, D.C.: American Forests.

American Planning Association. 2016. "AICP Code of Ethics and Professional Conduct." *American Planning Association*. https://www.planning.org/ethics/ethicscode.htm.

Anderson, L.M., and H.K. Cordell. 1988. "Influence of Trees on Residential Property Values in Athens, Georgia (U.S.A.): A Survey Based on Actual Sales Prices." *Landscape and Urban Planning* 15: 153–64.

Arbor Day Foundation. 2016. "What Is Tree City USA?" *National Arbor Day Foundation*. Accessed May 25. https://www.arborday.org/programs/treecityusa/about.cfm.

Beattie, Jeff, Cheryl Kollin, and Gary Moll. 2000. "Trees Tackle Clean Water Regs." *American Forests*.

Benedict, Mark A., and Edward T. McMahon. 2006. *Green Infrastructure: Linking Landscapes and Communities*. Washington, D.C.: Island Press.

Centers for Disease Control and Prevention. 2009a. "CDC - Healthy Places - Physical Activity." *Healthy Places*. http://www.cdc.gov/healthyplaces/healthtopics/physactivity.htm.

———. 2009b. "Water Sources | Public Water Systems | Drinking Water | Healthy Water | CDC." *Drinking Water*. http://www.cdc.gov/healthywater/drinking/public/water_sources.html.

———. 2012. "CDC - Public Water Systems FAQ - Public Water Systems - Drinking Water - Healthy Water." *Drinking Water*. http://www.cdc.gov/healthywater/drinking/public/drinking-water-faq.html.

Coder, Rim D. 1996. "Identified Benefits of Community Trees and Forests." FOR96-39. Athens, GA: The University of Georgia Cooperative Extension Service Forest Resources Unit.

Coley, Rebekah Levine, Frances E. Kuo, and William C. Sullivan. 1997. "Where Does Community Grow? The Social Context Created by Nature in Urban Public Housing." *Environment and Behavior* 29 (4): 468–94.

Cotrone, Vincent. 2015. "The Role of Trees & Forests in Healthy Watersheds: Managing Stormwater, Reducing Flooding, and Improving Water Quality." University Park, PA: Penn State Extension.

Curran, Winifred, and Trina Hamilton. 2012. "Just Green Enough: Contesting Environmental Gentrification in Greenpoint, Brooklyn." *Local Environment: The International Journal of Justice and Sustainability* 17 (9): 1027–42.

Danford, Rachel S., Chingwen Cheng, Michael W. Strohbach, Robert Ryan, Craig Nicolson, and Paige S. Warren. 2014. "What Does It Take to Achieve Equitable Urban Tree Canopy Distribution? A Boston Case Study." *Cities and the Environment (CATE)* 7 (1).

Donovan, Geoffrey H., and David T. Butry. 2010. "Trees in the City: Valuing Street Trees in Portland, Oregon." Landscape and Urban Planning 94: 77–83.

Donovan, Geoffrey H., David T. Butry, Yvonne L. Michael, Jeffrey P. Prestemon, Andrew M. Liebhold, Demetrios Gatziolis, and Megan Y. Mao. 2013. "The Relationship Between Trees and Human Health: Evidence from the Spread of the Emerald Ash Borer." *American Journal of Preventive Medicine* 44 (2): 139–45.

Durstine, J. Larry, Benjamin Gordon, Zhengzhen Wang, and Xijuan Luo. 2013. "Chronic Disease and the Link to Physical Activity." Journal of Sport and Health Science 2 (1): 3–11.

Edmondson, J.L., I. Stott, Z.G. Davies, K.J. Gaston, and J.R. Leake. 2016. "Soil Surface Temperatures Reveal Moderation of the Urban Heat Island Effect by Trees and Shrubs." *Scientific Reports* 6. doi:10.1038/srep33708.

Ernston, Henrik. 2013. "The Social Production of Ecosystem Services: A Framework for Studying Environmental Justice and Ecological Complexity in Urbanized Landscapes." *Landscape and Urban Planning* 109: 7–17.

Faber-Taylor, Andrea, Frances E. Kuo, and William C. Sullivan. 2001a. "Coping with ADD: The Surprising Connection to Green Play Settings." *Environment and Behavior* 33 (1): 54–77.

———. 2001b. "Views of Nature and Self-Discipline: Evidence from Inner City Children." *Journal of Environmental Psychology* 21.

Forest History Society. 2015. "U.S. Forest Service History: Gifford Pinchot (1865-1946)." *The Forest History Society*. http://www.foresthistory.org/ASPNET/People/Pinchot/Pinchot.aspx.

Fuller, Richard A., Katherine N. Irvine, Patrick Devine-Wright, Philip H. Warren, and Kevin J. Gaston. 2007. "Psychological Benefits of Greenspace Increase with Biodiversity." *Biology Letters* 3: 390–94.

Georgia Forestry Commission. 2005. "Tree Canopy Studies." *Georgia Forestry Commission.* http://www.gfc.state.ga.us/community-forests/management/tree-loss/.

Giarrusso, Tony, and Sarah Smith. 2014. "Assessing Urban Tree Canopy in the City of Atlanta; A Baseline Canopy Study." Atlanta: City of Atlanta Department of Planning and Community Development Forestry Division.

Giles-Corti, B., M.H. Broomhall, M. Knuiman, C. Collins, K. Douglas, K. Ng, A. Lange, and R.J. Donovan. 2005. "Increasing Walking: How Important Is Distance To, Attractiveness, and Size of Public Open Space?" *American Journal of Preventive Medicine* 28: 169–76.

Groth, Kelly, Michelle Miranda, and Natalie Sandberg. 2013. "Addressing Environmental Justice Through Zoning for Industry." Eugene, OR: City of Eugene.

Hauer, Richard J., Jessica M. Vogt, and Burnell C. Fischer. 2015. "The Cost of Not Maintaining the Urban Forest." *Arborist News*.

Heynen, Nik, Harold A. Perkins, and Parama Roy. 2006. "The Political Ecology of Uneven Urban Green Space: The Impact of Political Economy on Race and Ethnicity in Producing Environmental Inequity in Milwaukee." *Urban Affairs Review* 42 (1): 3–25. doi:10.1177/1078087406290729.

Jacobs, Jane. 1961. *The Death and Life of Great American Cities*. New York: Random House.

Jennings, Viniece, Cassandra J. Gaither, and Richard S. Gragg. 2012. "Promoting Environmental Justice Through Urban Green Space Access: A Synopsis." *Environmental Justice* 5 (1): 1–7.

Jones, Jill. Urban Forests: A Natural History of Trees and People in the American Cityscape. Viking, New York, 2016

Jiang, Bin, Dongying Li, Linda Larsen, and William C. Sullivan. 2016. "A Dose-Response Curve Describing the Relationship between Urban Tree Cover Density and Self-Reported Stress Recovery." *Environment and Behavior* 48 (4): 607–29. doi:10.1177/0013916514552321.

Kaplan, Rachel, and Stephen Kaplan. 1989. *The Experience of Nature: A Psychological Perspective*. Cambridge, UK: Cambridge University Press.

Kaplan, Stephen. 1995. "The Restorative Benefits of Nature: Toward an Integrative Framework." *Journal of Environmental Psychology* 15: 169–82.

Kaplan, Stephen, and Rachel Kaplan. 2003. "Health, Supportive Environments, and the Reasonable Person Model." *American Journal of Public Health* 93 (9): 1484–89.

Karlik, John F., and Dennis R. Pittenger. 2012. "Urban Trees and Ozone Formation: A Consideration for Large-Scale Plantings." 8484. University of California Agriculture and Natural Resources.

Kuo, Frances E. 2003. "Social Aspects of Urban Forestry: The Role of Arboriculture in a Healthy Social Ecology." *Journal of Arboriculture* 29 (3): 148–55.

Kuo, Frances E., and William C. Sullivan. 2001a. "Aggression and Violence in the Inner City: Effects of Environment via Mental Fatigue." *Environment and Behavior* 33 (4): 543–71.

———. 2001b. "Environment and Crime in the Inner City: Does Vegetation Reduce Crime?" *Environment and Behavior* 33 (3): 343–67.

Landry, Shawn M., and Jayajit Chakraborty. 2009. "Street Trees and Equity: Evaluating the Spatial Distribution of an Urban Amenity." *Environment and Planning A* 41: 2651–70.

Lawrence, H.W. 2006. *City Trees, a Historical Geography from the Renaissance through the Nineteenth Century*. Charlottesville: University of Virginia.

Lee, A.C.K., and R. Maheswaran. 2010. "The Health Benefits of Urban Green Spaces: A Review of the Evidence." *Journal of Public Health* 33 (2): 212–22.

Lerner, and Poole. 1999. "The Economic Benefits of Parks and Open Space." The Trust for Public Land.

Lovasi, G.S., J.W. Quinn, K.M. Neckerman, M.S. Perzanowski, and A. Rundle. 2008. "Short Report: Children Living in Areas with More Street Trees Have Lower Prevalence of Asthma." *Journal of Epidemiology and Community Health* 62: 647–49.

Maskaly, Jon, and Lyndsay N. Boggess. 2014. "Broken Windows Theory." *The Encyclopedia of Theoretical Criminology*.

McDonald, Robert I. 2015. *Conservation for Cities: How to Plan & Build Natural Infrastructure*. Washington, D.C.: Island Press.

Mitchell, Richard, and Frank Popham. 2008. "Effect of Exposure to Natural Environment on Health Inequalities: An Observational Population Study." *The Lancet* 372: 1655–60.

Nasar, J.L., and B.S. Fisher. 1993. "'Hot Spots' of Fear and Crime: A Multi-Method Investigation." *Journal of Environmental Psychology* 13: 187–206.

National Urban and Community Forestry Advisory Council. 2015. "Ten-Year Urban Forestry Action Plan: 2016-2026." University of Virginia Institute for Environmental Negotiation. http://www.urbanforestplan.org/wp-content/uploads/2015/11/FinalActionPlan_Complete_11_17_15.pdf.

Newman, Oscar. 1972. *Defensible Space: Crime Prevention through Urban Planning*. New York: Macmillan.

———. 1996. "Creating Defensible Space." General Technical Report. U.S. Department of Housing and Urban Development.

Nowak, David J. 2002. "The Effects of Urban Trees on Air Quality." General Technical Report. Syracuse, NY: USDA Forest Service, Northern Research Station.

Nowak, David J., and Eric J. Greenfield. 2012. "Tree and Impervious Cover Change in U.S. Cities." *Urban Forestry & Urban Greening* 11: 21–30.

Nowak, David J., and Jeffrey T. Walton. 2005. "Projected Urban Growth (2000-2050) and Its Estimated Impact on the US Forest Resource." *Journal of Forestry* 103 (8): 383–89.

Office of Disease Prevention and Health Promotion. 2008. "Physical Activity Guidelines for Americans." U.S. Department of Health and Human Services.

Pincetl, Stephanie. 2010. "Implementing Municipal Tree Planting: Los Angeles Million-Tree Initiative." *Environmental Management* 45: 227–38. doi:10.1007/s00267-009-9412-7.

Pincetl, Stephanie, Thomas Gillespie, Diane E. Pataki, Sassan Saatchi, and Jean-Daniel Saphores. 2013. "Urban Tree Planting Programs, Function or Fashion? Los Angeles and Urban Tree Planting Campaigns." *GeoJournal* 78: 475–93.

Pretty, J., J. Peacock, M. Sellens, and M. Griffin. 2005. "The Mental and Physical Health Outcomes of Green Exercise." *International Journal of Environmental Health Research* 15 (5): 319–37.

Randolph, John. 2003. *Environmental and Land Use Planning and Management*. 2nded. Washington, D.C.: Island Press.

Schwab, James C. 2009. "Planning the Urban Forest: Ecology, Economy, and Community Development." General Technical Report 555. Planning Advisory Service. Chicago, IL: American Planning Association.

Schwarz, Kirsten, Michail Fragkias, Christopher G. Boone, Weiqu Zhou, Melissa McHale, J. Morgan Grove, Jarlath O'Neil-Dunne, et al. 2015. "Trees Grow on Money: Urban Tree Canopy Cover and Environmental Justice." *PLoS ONE* 10 (4): 1–17. doi:10.1371/journal.pone.0122051.

Seila, A.F., and L.M. Anderson. 1982. "Estimating Costs of Tree Preservation on Residential Lots." *Journal of Arboriculture* 8: 182–85.

———. 1984. "Estimating Tree Preservation Costs on Urban Residential Lots in Metropolitan Atlanta." Research Paper 48. Macon, GA: Georgia Forestry Commission.

Shaffer, G.S., and L.M. Anderson. 1985. "Perceptions of the Security and Attractiveness of Urban Parking Lots." *Journal of Environmental Psychology* 5: 311–23.

Stanley, Paul. 1976. "Crime Prevention Through Environmental Design: A Review." General Technical Report. Canada: Solicitor General of Canada.

Stone, Brian, and John M. Norman. 2006. "Land Use Planning and Surface Heat Island Formation: A Parcel-Based Radiation Flux Approach." *Atmospheric Environment* 40: 3561–73. doi:10.1016/j.atmosenv.2006.01.015.

Strife, S., and L. Downey. 2009. "Childhood Development and Access to Nature: A New Direction for Environmental Inequality Research." *Organization and Environment* 22 (1): 99–122.

Sullivan, William C., Frances E. Kuo, and Stephen F. DePooter. 2004. "The Fruit of Urban Nature: Vital Neighborhood Spaces." *Environment and Behavior* 36 (5): 678–700.

Suminski, R.R., W.S. Carlos Poston, R.L. Petosa, E. Stevens, and L.M. Katzenmoyer. 2005. "Features of the Neighborhood Environment and Walking by U.S. Adults." *American Journal of Preventive Medicine* 28 (2): 149–55.

Ulrich, Roger S. 1981. "Natural Versus Urban Scenes: Some Psychophysiological Effects." *Environment and Behavior* 13 (5): 523–56.

———. 1984. "View through a Window May Influence Recovery from Surgery." *Science* 224: 3.

Ulrich, Roger S., Robert F. Simons, Barbara D. Losito, Evelyn Fiorito, Mark A. Miles, and Michael Zelson. 1991. "Stress Recovery During Exposure to Natural and Urban Environments." *Journal of Environmental Psychology* 11: 201–30.

US Environmental Protection Agency. 2016. "Criteria Air Pollutants." Policies and Guidance. https://www.epa.gov/criteria-air-pollutants.

———. 2016. "Environmental Justice." Collections and Lists. Accessed June 2. https://www.epa.gov/environmentaljustice.

van den Berg, Agnes E., Jolanda Maas, and Robert A. Verheij. 2010. "Green Space as a Buffer between Stressful Life Events and Health." *Social Science & Medicine* 70: 1203–10.

Wells, Nancy M. 2000. "At Home with Nature: Effects of 'Greenness' on Children's Cognitive Functioning." *Environment and Behavior* 32 (6): 775–95.

Wolch, Jennifer R., Jason Byrne, and Joshua P. Newell. 2014. "Urban Green Space, Public Health, and Environmental Justice: The Challenge of Making Cities 'Just Green Enough.'" *Landscape and Urban Planning* 125: 234–44.

Wolf, Kathleen L. 2008. "City Trees, Nature and Physical Activity: A Research Review." *Arborist News*.

Wolf, K.L. 1999. "Nature and Commerce: Human Ecology in Business Districts." In *Building Cities of Green: Proceedings of the 9th National Urban Forest Conference*, 4. Washington, D.C.

Wolfe, Mary K., and Jeremy Mennis. 2012. "Does Vegetation Encourage or Suppress Urban Crime? Evidence from Philadelphia, PA." *Landscape and Urban Planning* 108: 112–22.

Wolf, Kathleen L., and Alicia ST Robbins. "Metro nature, environmental health, and economic value." *Environmental Health Perspectives (Online)*123, no. 5 (2015): 390.

World Health Organization. 2016. "WHO | Noncommunicable Diseases." *WHO*. http://www.who.int/topics/noncommunicable_diseases/en/.